1. An astronaut travels from the Earth to a distant star system, which is 15.0 *light-years* away, at constant velocity and then returns at the same speed. 1 *light-year*=1 c·year. The round trip takes 28.0 years according to the astronaut.

   (a) At what speed was the astronaut traveling?

   (b) How much time has elapsed on the Earth?

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2. Two space ships are observed to have the velocities as shown in the figure.

   (a) Determine the *velocity* of B with respect to A.

   (b) Ship A carries a Doppler radar system with a proper frequency of 600 MHz. What would be the frequency heard by A of the 'radar echo' from B?

Stars are composed of mostly hydrogen. If the spectral line from the $4 \rightarrow 2$ transition in hydrogen (486 nm) is observed from the Earth at a wavelength of 729 nm, what is the *velocity* of this star with respect to the Earth? Assume that the star moves along the line joining the star and the Earth observer.

A neutron (m_n=940 MeV/c^2) has a momentum of 1290 MeV/c.

(a) Determine whether or not this particle should be treated relativistically.

(b) Calculate the speed of this particle.

Monochromatic γ-rays (high-energy photons) are incident on a proton target (m_p=938 MeV/c^2). Scattered γ-rays are determined to have an energy of 170 MeV for a scattering angle of 135°.

(a) What is the incident energy of the γ-rays?

(b) Find the emission angle of the recoiling protons.

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6. Consider the single-electron ion Li^{++}. Your calculations should be done with 4 significant figures.

   (a) The ion is promoted from the ground state to an excited state via the absorption of a a photon of energy 108.8 eV. What wavelengths can be emitted as the ion returns to the ground state?

   (b) Determine the radius of the ground state of this ion.

   (c) Find the deBroglie wavelength of the electron in the ground state of this ion.

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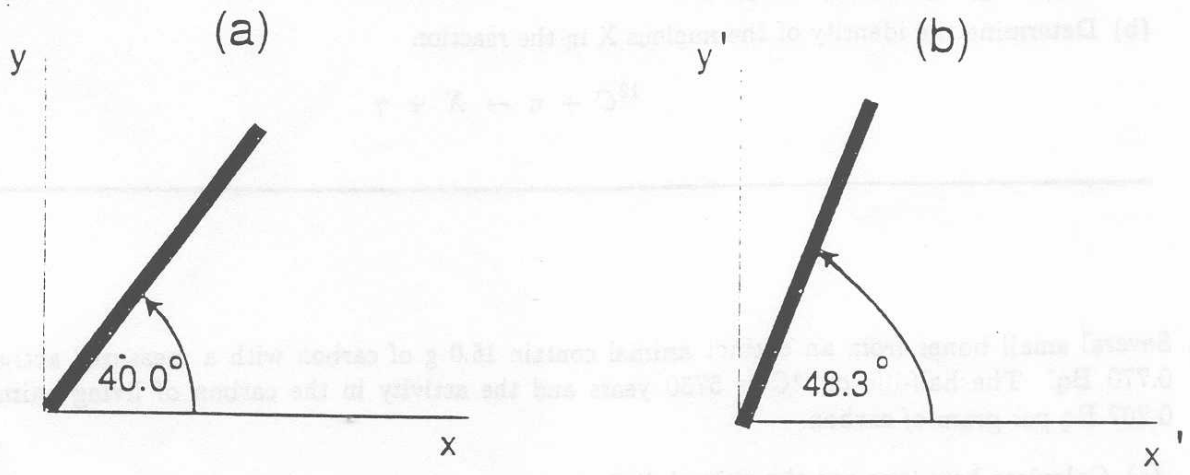
7. In it's rest frame a rod has an orientation of 40.0° with respect to the x-axis as shown in part (a) of the figure below. However an observer sees the bar moving with velocity v along the x-axis. To the observer the rod appears to be oriented at a angle of 48.3° with respect to the x-axis as shown in part (b) of the figure. Calculate the speed v. (Note: the diagrams are not drawn to scale.)



8. When the intensity of blackbody radiation from a small object is plotted versus wavelength it is found that the maximum intensity occurs at a wavelength of 1.24×10^{-6} m. The object has a surface area of 2.55 cm^2 and can be considered to be a perfect blackbody radiator. At a distance r from the object the intensity of radiation is measured to be 3.92 W/m^2.

   (a) Caculate the temperature of the object.

   (b) Calculate the distance r.

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9. A photoelectric cell is connected to a circuit in which the current due to the photoelectrons can be measured. It is found that light of frequency 2.12×10^{15} Hz gives rise to photoelectrons with a maximum speed of 1.33×10^{6} m/s.

   (a) Calculate the work function of the material.

   (b) Calculate the stopping voltage if the frequency of incident light is halved to 1.06×10^{15} Hz.

   (c) If the incident light has the original frequency of 2.12×10^{15} Hz but its intensity is doubled, describe the effects on the maximum speed of the electrons and on the current in the ciruit.

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10. (a) Determine if ^{64}Zn can spontaneously decay by the emission of an alpha particle, and if so, find the energy released by the process.

    (b) Determine the identity of the nucleus X in the reaction

$$^{12}C + n \rightarrow X + \gamma$$

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11. Several small bones from an extinct animal contain 16.0 g of carbon with a measured activity of 0.770 Bq. The half-life of ^{14}C is 5730 years and the activity in the carbon of living animals is 0.267 Bq per gram of carbon.

    (a) Calculate how long ago the animal died.

    (b) Calculate the number of ^{14}C atoms present in the bones when the activity is 0.770 Bq.

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12. Consider the fusion reaction

$$^{4}He + {}^{4}He + {}^{4}He \rightarrow {}^{12}C$$

    (a) How many Joules of energy are released by the above reaction?

    (b) Suppose that during each second a total mass of 0.020 g of ^{4}He is fused in a reactor by the above reaction. Calculate the power output of the reactor.
